# Towards a kansei-based user modeling methodology for eco-design

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**ABSTRACT**
We propose here to highlight the benefits of building a framework linking *Kansei Design* (KD), *User Centered Design* (UCD) and *Eco-design*, as the correlation between these fields is barely explored in research at the current time. Therefore, we believe Kansei Design could serve the goal of achieving more sustainable products by setting up an accurate understanding of the user in terms of ecological awareness, and consequently enhancing performance in the Eco-design process. In the same way, we will consider the means-end chain approach inspired from marketing research, as it is useful for identifying ecological values, mapping associated functions and defining suitable design solutions. Information gathered will serve as entry data for conducting scenario-based design, and supporting the development of an Eco-friendly User Centered Design methodology (EcoUCD).

**Keywords**
Kansei design, experience design, user modeling, user centered design, Eco-design.

**INTRODUCTION**
This paper aims to achieve two objectives: firstly it reviews the literature in order to find approaches from various topics that may be relevant to linking the fields of *Eco-design*, *User Centered Design* and *Kansei Design*. And next, it compiles these ideas and proposes a theoretical model that describes this particular association. Thus we will provide here a brief overview of the notable breakthroughs in these areas and review the most relevant technologies developed in terms of user involvement. We will focus especially on trends in modeling that allow integration with the field of Eco-design. Thus, this paper is divided into six parts, ranging from the general to the specific. Part 1 presents an overview of the analysis of the state of the art results. Part 2 introduces the pathway with a general assertion on sustainability and its connection with *Eco-design* and *Green Kansei*, and we will discuss what is known as *Eco-design*. Part 3 evaluates the capabilities of *Eco-design* approaches to integrate users. Part 4 focuses on the user and makes a general statement on the current principles for integrating and evaluating users in user centered design studies. Part 5 goes further toward an advanced definition of users by asserting Kansei-based factors that we call *Eco-Kansei*, then describing what is known as *Green Kansei* for *Eco-design*. And finally, we will conclude on part 6 by suggesting a new theoretical model as an initial framework of attempting to merge the processes of Kansei Design and User Centered Design and Eco-design.

## 1 GENERAL OVERVIEW

To begin with, we will start by giving an overview of the results of a state of the art review. Indeed, the basic context of our work is clearly considered as cross disciplinary and requires a wide and macro vision of the subject. The related state of the art tries to focus on a set of specific themes, identified in some relevant studies, which may be linked to the main fields discussed above. These are:

- Studies that propose an integration of users in the design process, such as *"User Centered Design"* studies (UCD),
- Studies that provide a characterization of emotions and subjectivity onto the definition of product, such as *"Kansei / Affective Design"* (KD),
- Studies that provide an environmental consideration in the design process, or *"Eco-design"*.

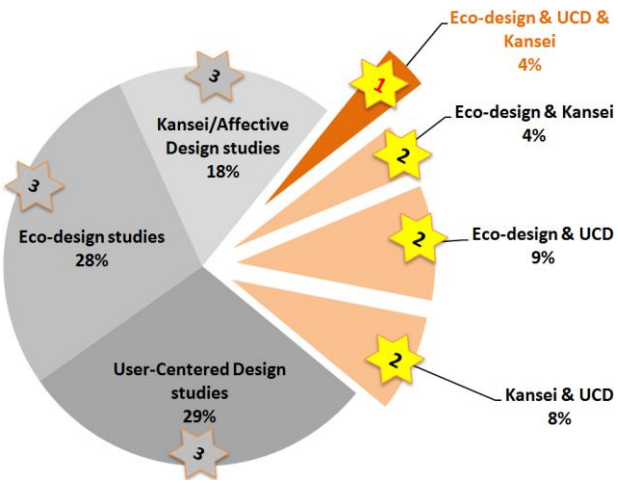


**Figure 1. Key fields distribution among 147 references.**

As a consequence, the intersection of these three areas allows us to define some relevance levels ranging from 1 to n, as 1 is the closer to the objective. Indeed, the first level is reached once a study which combines the three fields is identified; the level 2 if an association between only two fields is found, and so on. It would be at level 3 if we focus only on key areas, and finally, at level 4 and if we are interested in other areas more or less divergent

from the three initial themes. These studies may be of minor interest but would likely contain useful information otherwise. Figure 1 above shows a brief quantitative summary of the relative findings.

The result lets us state that no significant amount of elements were found regarding the crossed result, allowing us to show that there is a scientific gap, and this actual investigation is a valuable study that could serve as an innovative support for the research field.

## 2 FROM SUSTAINABILITY TO ECO-DESIGN

This second part introduces the general concepts of Eco-design and Green Kansei. We propose to show the place of these key areas into a wider scale by emphasizing their interaction with global sustainability development. Indeed, sustainability has gathered more and more interests over the past decades, regarding both the fields of industry and research. Sustainability is a global principle which covers multiple dimensions such as social, economical and environmental interests [92]. The latter - the environmental issues - turn out to be more related than others, and thus more often associated with sustainability principles. By stating a brief history, politics were the first concerned with the environmental impact, followed by administration collectivities and some pro-environmental organizations, then lately expanded at a wider scale. Nowadays, embracing eco-friendly principles almost become a fashion practice among concerned stakeholders in many fields, as green concept turns out to be an interesting issue. Today, that global trend brought by ecological interests is taken into account into product design development, through the principle of the so well-known Eco-design, or design for environment.

### 2.1 Sustainable Green Kansei

Product design and Eco-design are closely related to the sustainability development, this relationship is mainly inclusive, as it is presented in the model of Tischner and Charter [81], where they clearly describe the link between product design, Eco-design, sustainable design, and sustainable development. Elias explains how product design is linked to the global sustainability process [21].

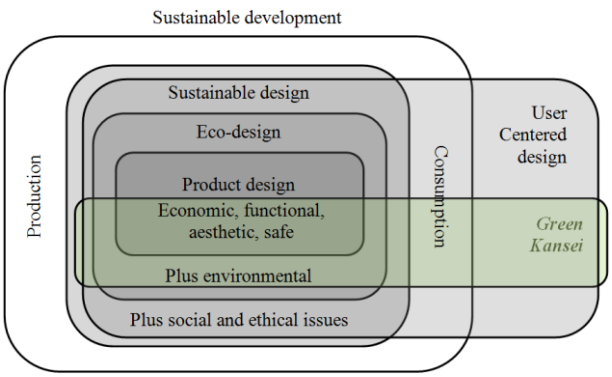


**Figure 2. Eco-design and sustainable development (Adapted from Tischner *et al.* [81] in [21])**

Today, further inclusion should be considered aiming towards an ecological implication for Kansei. In fact, Kansei design must be regarded as the integration of the subjective evaluation of Kansei factors into sustainable design. Mapping the Kansei design would lead to the enrichment of Tischner and Charter's model. As shown in Figure 2 above, this inclusion allows us to introduce the ecological part of Kansei through the notion of "*Green Kansei"*.

*Eco-design* is defined by the International Standard Organization as the integration of environment aspects into product design and development ISO/TR 14062 [1]. Another definition of Eco-design comes from the European Union. In fact, according to Directive 2005/32/EC for Energy products [27], Eco-design means the integration of environmental aspects into product design in order to improve environmental performance of the EuP throughout its whole life cycle.

Two directives related to Eco-design have been adopted by the European Union: Directive 2005/32/EC [27] and Directive 2009/125/EC [28]. The first directive regulates *energy-using products* (*EuP*) while the second is its replacement and regulates *energy-related products* (*ErP*). The difference between *EuP* and *Erp* is related in the table 1 below [91].

| **Energy-using Products** | **Energy-related Products** |
|---|---|
| • require energy (electricity, fossil fuels or renewable energy) input to work as intended;<br>• includes products that generate, transfer or measure energy;<br>• excludes products that transport people or goods. | • impact energy consumption during their use;<br>• examples include construction materials such as windows & insulation and water-using products such as shower heads & tap;<br>• includes EuP;<br>• excludes products that transport people or goods. |

**Table 1. Difference between EuP and Erp [91]**

Eco-design objectives aim to minimize the impact of the product's life cycle on the environment, factoring energy consumption, carbon emission, materials, packaging and transport, chemical substances, potential toxicity, recyclability and durability through the product lifecycle.

### 2.2 Eco-design tools & methodologies

We stated that Eco-design methodologies aim to support the creation of products which are less harmful for the environment. In this way, designing with sustainable objectives turns out to be a great challenge for manufacturers, as it implies for designer to understand the whole life cycle of the product. Life Cycle Assessment (LCA) is the first tool that is commonly used for Eco-design, from raw materials extraction, manufacturing, packaging, distribution, product use to the final disposal. An efficient Eco-design method must take into account the environmental impact of each phase of the product lifecycle.

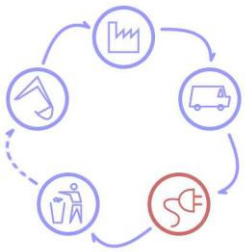

**Figure 3. The product lifecycle [10]**

In the same way, *Environmental Effect Analysis* (EEA) is used to identify the product eco-profile, by retrieving the relevant factors for the reduction of the environmental impact during all lifecycle stages.

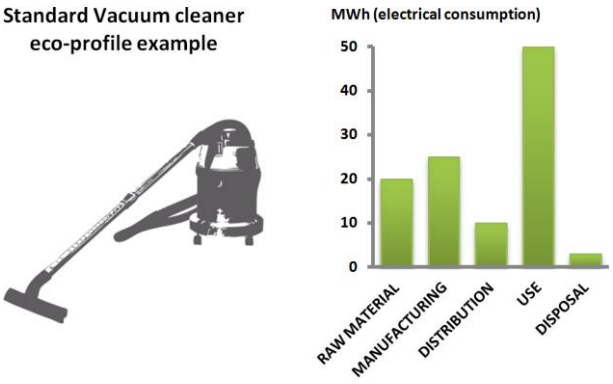


**Figure 4. Example of standard vacuum cleaner eco-profile [25]**

Current Eco-design methodologies propose guidelines in order to formalize the design requirements retrieved from EEA [10] [79].

Software such as *"Eco-design Pilot"* [24,89,90] exists helping to assess the EEA on the product lifecycle. Various interesting Eco-design methods are also available in the literature [48,49,79,80]. The use phase is also taken into consideration by some studies such as [10,50]. In addition, talking about the specific use phase, introducing the user himself in Eco-design is the main interest of the next chapter.

## 3 INTRODUCING THE USER IN ECO-DESIGN

After giving an overview of Eco-design principles, we intend to see in this third part the possibilities for integrating users in its main concept.

In the first place, designing for the environment brings a strong enthusiasm among scientists in several research fields, whereas various methodologies and tools were implemented and validated through a predictive analysis of the whole product lifecycle. *Life Cycle Assessment* (LCA) runs from the extraction of raw materials to disposal of the product, passing through the manufacturing, distribution and use phases – see Figure 10 – , and helps us understand the environmental impact of a designed product. The use phase is the key specific element that drives our current work, and brings the basic assumption of our statement. Indeed, the use stage is an important step of the product lifecycle, as it provides a sizeable part of environmental impact. It appears that environmental performance in the use phase is interesting and difficult to assess, while the available indicators in terms of environmental performance are merely about product-related rates related to energy consumption or carbon dioxide rejection.

Moreover, impacts that occur during the use phase are often determined by analyzing user's behavior [7]. The behavior of the user dealing with products is interesting to evaluate and later change in favor of a more sustainable practice. Influencing the behavior of users is therefore a difficult task. However, designers have the tools to reduce the environmental impacts of the product use, and supporting changes in that user behavior towards more sustainable behaviors [7,26,88,93].

### 3.1 Mapping ecological user behavior

A green product is defined as a product which complies with the most interesting environmental issues throughout its life cycle [68]. From a general point of view, the association of the product design with environmental awareness necessarily involves a consideration of human factors [77]. Product design for sustainable environment is a "human-centered." discipline. Following this statement, *Eco-design* and *User-centered design* can therefore be considered as closely related. Thus, in the category of specific design methods, we can cite Lilley's model, for example [46], in her approach "Design for Sustainable Behavior" in which she explores how design can be used to influence the behavior of users to shift towards more sustainable practices. She describes three strategies to change user behavior and evaluates their effectiveness, by using a part of design methodologies found from the literature and also by enriching them with results from the analysis of a case study.

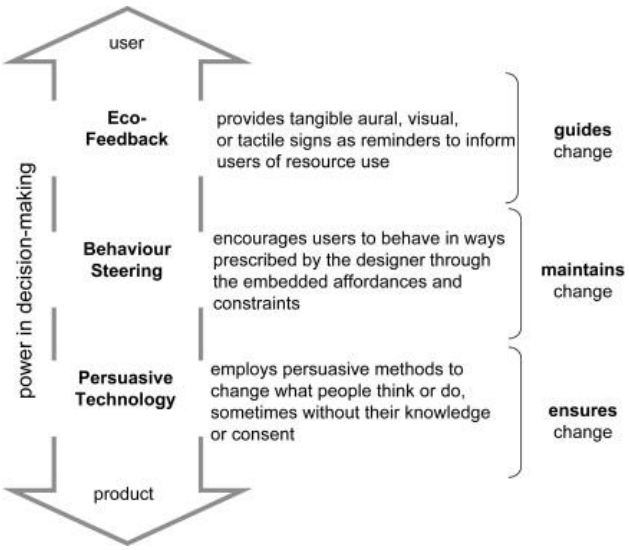


**Figure 5. Three strategies for designing sustainable behaviour [46]**

These three strategies are the main current approaches that may be considered throughout the scientific community as frameworks for a user-centered eco-design methodology.

- Eco-feedback / Eco-retroaction [38,54],
- Behavior steering [4,39],
- Persuasive technologies [5,29].

Lilley's model was later reused, enriched and updated by other authors, for mapping the association of user behavior and environment [7]. It appears then that the user can be affected by the information presented to him and his behavior could be influenced in this case.

## 4 MODELING USERS IN USER CENTERED PRACTICES

In this fourth part, we will focus especially on user elicitation and make a general statement on the current principles for integrating and evaluating users in generic user centered design studies. We will talk about User Experience, and the importance of designing this experience using User Centered Design methodologies. In addition, we will see why usability assessment tools are useful for conducting this evaluation.

However, remaining close to environmental considerations, we can assert that the application of Eco-design strategies has significantly reduced the environmental impacts of the life cycle of the product [45]. Moreover, in order to understand the use phase, it is essential to have information about the user in order to adapt the product to his/her characteristics and preferences. And by "the user", we mean both the physical user, with his cognitive and psychological patterns and also the context of use. Therefore, it is necessary to merge the whole environment of the user to define the use phase. Nevertheless, such investigation requires a complete understanding of the user-product interaction process. According to the field of *User Centered Design* or *Human Centered Design*, users have been taken into account in the design process for years. Users may also be involved in the early design process through the practice of Participatory Design [61].

These user centered studies point out the user's characteristics and let their needs to be expressed. The main advantage of relying on such methodologies is rather important, since these practices allow enhancing the usability performance of the product by matching the user's needs with product design parameters. Thus, defining the user leads to the User Modeling techniques (UM). User Modeling is an area that has been widely considered in the research community for the past forty years. Early User Modeling techniques commonly refer to the area of Computer Science, as it is known more precisely in the Information Science and Artificial Intelligence, and basically used to improve the user implication on Hypermedia and Adaptative Systems. Later evolutions concern extensive implications on Human-Computer Interaction, Interface Design and today more and more implemented in consumer product design. Various techniques are used in user modeling, such as heuristic-based formal evaluation, brainstorming, expert reviews in sociology or ergonomics, direct tests on physical or virtual prototypes, acceptability surveys, interviews, observations, participatory design, task analysis, focus group, scenarios production and application, experience through ecological-economical paper, and ethnographic approaches [12].

### 4.1 Designing the User Experience

From this point of view, products are perceived as perfect if they give the most suitable user experience. In order to reach that objective, two major steps are necessary. The first step is to assess a correct elicitation of the target user through User Modeling (UM), and the second is to design the suitable experience through the interaction of this user with the product, also referred as Experience Design (XD). Following this statement, Experience Design (XD) and User Modeling (UM) are considered as user-centered studies, as they may be linked with the field of User Centered Design (UCD)

### 4.2 User Centered Design overview

User Centered Design (UCD) is a multidisciplinary design practice based on the active involvement of users. The UCD is considered the key to ensuring maximum usability of the product. The aim of this approach is then to improve the understanding of use and task requirements, thus ensuring the optimization of iterative phases between design and evaluation. To help justify its importance, the UCD approach is formalized in the International Standard Organization (ISO), making it a useful tool for any user-focused approach [3]. In practical terms, UCD is currently applied in industrial firms of all sizes, and stimulates technological development through the early inclusion of end users [53].

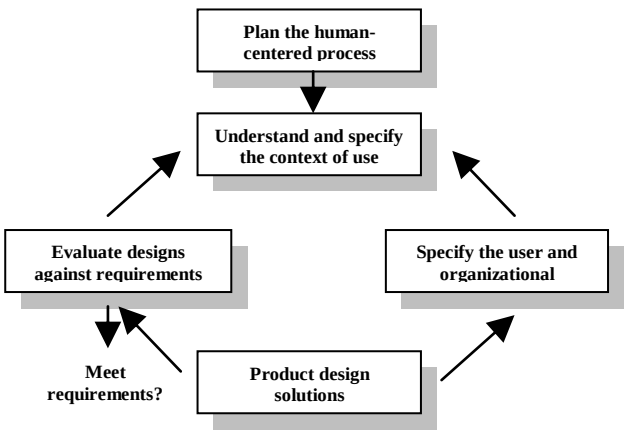


**Figure 6. Key human-centered design activities (from ISO 13407)**

The integration of the user in the design process has taken a while be mature [51,78]. Some authors demonstrate that this practice may also become an important factor of innovation [70]. The user himself is not the only entity role in user-centered design, the

context of use is an important step in the analysis that has been taken into account. Various studies demonstrate the importance of this vision [76,88].

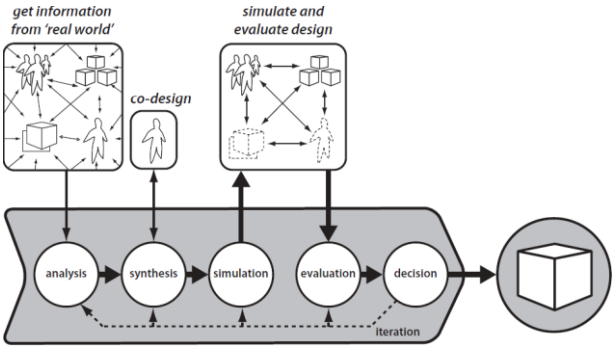


**Figure 7. User Centered Design Process including context of use [72,88]**

### 4.3 Usability assessment as a validation tool

Dealing with the analysis of use phase leads us to consider usability assessment methodologies. This step helps us define usability goals and validate the potential user-friendliness of any product concept. Usability tests that are conducted throughout product development to guide the design are called formative. These tests focus on identifying the strengths and weaknesses of the product and contribute to their iterative improvement. In contrast, tests that are conducted at the end of product development are called [23]. Usability is often defined as "*the degree to which a product can be used by specified users to achieve defined objectives with effectiveness, efficiency and satisfaction in a specified context of use*". Effectiveness is defined as "*the accuracy and completeness with which users are able to achieve specific goals*", efficiency as "*the provision of resources expended in relation to the accuracy and completeness with which users will have achieved the objectives* ", and satisfaction as "*comfort in use, and a positive attitude towards subjective interaction with the product*" [2]. The usability of a product is evaluated by analyzing data collected by different methods. Dumas & Salzman drew up a list of comparative methods in describing the basics of the different techniques, their strengths and weaknesses, measuring their characteristics, their validity and reliability, and how they are applied to the development and evaluation of products [23]. The table 2 below summarizes briefly these methods.

| Categories | Principles |
|---|---|
| *Usability testing* | Usability testing is an empirical method for uncovering the strengths and weaknesses in the usability of a product or system and, less commonly, for measuring or comparing its usability. |
| *Usability inspections* | The methods that emerged in the 1990s have moved in two directions: expert reviews, in which individual specialists inspect a user interface; and walkthroughs, in which small teams of developers led by a usability specialist use a group process to explore how tasks are performed. |
| *Survey, Interviews & focus group* | Traditionally, surveys have been used to reach large samples of users, interviews have been used to probe a small number of users more deeply, and focus groups have been used to stimulate users to express unique responses |
| *Field methods* | Field methods are a collection of techniques for studying users, their activities, and their interaction with products in real-world contexts. These methods are an important supplement to usability testing, heuristic evaluation, and surveys. |

**Table 2. Usability assessment methodologies [23].**

Among the ideas put forth in the literature on evaluation of usability and affordance in design [58, 85], it appears that ethnographic methods are particularly suitable for considering environmental impact, regarding the quality of immersion that allows collecting real data and the *in situ* characteristic of the observation [23].

## 5 GREEN KANSEI FOR ECO-DESIGN

This fifth part summarizes these different visions of user and then introduces a further user definition by integrating Kansei-based factors or *Eco-Kansei*. The various fields we introduced in the previous chapter will serve as concrete support for its integration with the Kansei notions. That is the main innovative point that makes this assertion an interesting support for a multidisciplinary work.

### 5.1 About Kansei & Kansei Engineering

The importance of pointing out the subjective perceptions associated with the emotion was put forward by several scientists [31,60]. Various techniques have emerged to take into account the integration of these features in the product design. Two major research streams about emotional approach exist with fairly similar views [11].

- On the first hand, the concept of Kansei Engineering coming from Japan, initially developed by Mitsuo Nagamachi proposes to measure the subjective values associated with the products and translate them into product attributes [56,13,75,52,19],
- On the other hand, there is an European approach called "Emotional Design" used by authors such as Norman or Overbeeke [64,31,60,73] that would be rather associated with Experience Design, and the creation of feelings of attachment to the product.

Thus, Kansei Engineering measures emotional needs and translates them into design elements, in order to provide end-users with greater satisfaction and product acceptance. The transcription of the subjective characteristics experienced by the user (Kansei) towards perfect design elements remains one of the main challenges of emotional design [64]. Various methods to measure subjective emotions exist from statistics-based methods to those based on neural networks [17, 22].

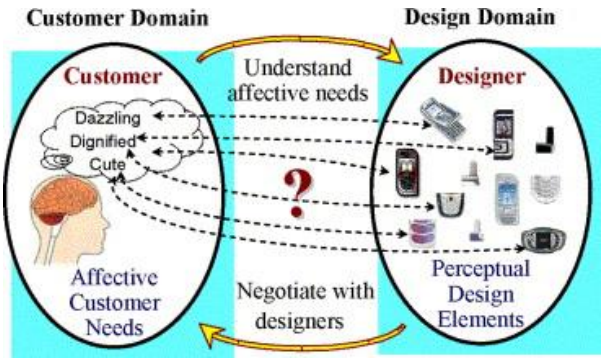


**Figure 8. Mapping model in affective design [40].**

There are many examples of affective dimensions considered in the literature, especially related to usability considerations which are relevant for our work because they directly affect user behavior. Examples are found in electronics [47], computer interfaces [41], and food products [42]. It is also shown that errors or "*faux pas"* occur when product use leads to negative emotional responses and thus to a loss of usability [83]. Furthermore, Han proposes to model emotional response with respect to product usability [33]. His study provides a systematic approach for improving the emotional responses (objective and subjective) of consumer electronics. His approach can be used in the design and evaluation phase of the development process. It can help designers and developers identify critical design elements, diagnose usability problems, and predict the level of usability of consumer electronic products. The approach developed in this study is also applicable to other consumer products (such as appliances, automotive, communication devices, and so on), subject to minor changes. Usability is often defined along two main dimensions: a dimension in terms of *performance objective* and a *subjective dimension* related to the image or impression aroused. Subsequently, these *subjective dimensions* of usability may be easily linked to *intangible Kansei factors*, and satisfy our methodology principle.

### 5.2 Eco-Kansei

*Green Kansei* can be introduced as a central topic in our work. Indeed, we believe users' environmental awareness is closely related to the subjective notions usually covered by Kansei.

Both *concrete* and *abstract* Kansei factors may be taken into account through Eco-design, as they help linking ecological-awareness values and/or provoked emotions to product attributes. For example, concrete (or *tangible*) factors which are related to product parameters such as green color, forms associated with natural elements, light materials or texture may be related to environmental awareness. Abstract (or *intangible*) factors could also be set as parameters for understanding the user (user's terminal values, life experience, emotion associated with a particular content, opinions, culture [34,35,36,69], moods and semantics surrounding the product [71,63,66].

We could sum up these elements into the term of *eco-X*, as we talk about *eco-Kansei* factors regarding the Kansei factors for environment, such as *eco-values*, *eco-moods*, *eco-culture*, *eco-emotions*, and so on.

These elements are useful to assess a complete understanding of users and their relationship with environmental issues. They help design user profiles or personas that will fit perfectly with the usability goals related to the environment. These elements will be useful as well for completing an UCD process.

### 5.3 Towards an Eco-User profile

In order to profile the user, we will introduce here what is known about *persona*. A *persona* is a user profile that allows designers to highlight the objectives of the individual during the use of an artifact. This is an archetypal representation of actual or potential users of the product, which aims to highlight the behavior patterns of users, their goals and motivations, with a fictional description [8].

*Personas* can focus on the user and the context of use with their fictitious characteristics [32,37]. The integration of *personas* has many advantages in product design [55], particularly on understanding the needs of the user but also the communication between designers. Several features should be considered for the identification of user profiles represented by a *persona* [43], in this case, these features are detailed below:

| Categories | Characteristics |
|---|---|
| *Personal characterisitcs* | • Age, sex, education, job type, socio-economic status, role in organization.<br>• Lifestyle, personality, emotions and attitudes (e.g. toward using a technology).<br>• Skills.<br>• Physical abilities and constraints, e.g. poor eyesight, color blindness, etc. |
| *Task related characteristics* | • Goals and motivation.<br>• Tasks<br>• Usage (heavy vs. light, frequency, indirect or remote).<br>• Training and experience (from novice to expert). |
| *Geographic and social characteristics* | • Location: regions, countries, continents, market areas.<br>• Cultures and other circumstances.<br>• Social connections, societies, organizations. |

**Table 3. Persona characteristics [43].**

The creation of the *personas* should be based on established real data [30,67,62], which can be collected directly from users, or through more indirect sources [14]. Indeed, various market research surveys exist, regarding environmental behaviors. They could be useful for pointing out the segmentation of users and creating *personas* [20,82].

### 5.4 Scenario analysis

Analyzing the use phase must not be seen as a static process. User behaviors evolve while performing any task. Thus, we introduce scenario analysis in order to assess this dynamic evolution in the use phase. In fact, *personas* and scenarios are closely related. In other words, it would be interesting to focus on scenarios as they share on the face of the attributes and similar principles with the *personas*. Scenarios are stories. These are stories about people and their activities [15]. However, the literature emphasizes that the combination of scenarios and personae would be more convincing because the scenarios are less effective when their construction is not associated with personae [32,57].

### 5.5 From values to product attributes

The Means-End Chain (MEC) theory in Marketing research could highlight the links between the identified values and product attributes, through a simple means-end chain. A means-end chain is a simple knowledge structure containing interconnected meanings through which product attributes are seen as means-to-ends or personal values [6,87]. The product's attributes, consequences and values (ACV) and, above all, the links consumers establish between them, constitute the essence of the MEC [18].

## 6 TOWARDS A MODEL PROPOSAL

In this final part, we will conclude by proposing a new theoretical model as an initial framework attempting to merge the processes of *Kansei Design*, *User Centered Design* and *Eco-design*. This model is created according to the previous statements of each part discussed in the article.

By describing the state of the art, we noticed that few studies attempted to merge Kansei and Eco-design. Indeed, the various proposed approaches found in the literature [44,17,16] are a source of interesting ideas, but the diversity of applications does not confirm their relevance to global methods of eco-design. The impacts identified are still focused on one single phase of the life cycle and does not take into account effects on other cycles. From a methodological point of view, an interesting view of the first has been already advanced and allowed the integration of Kansei, by considering *Experience Design* and methods of *Eco-design*, and then taking into account human values, semantics, functions and affordance [12].

In order to settle ideas about our model, we will consider these various statements, following the literature review:

| |
|---|
| Standard Design model is used as a first support of the methodology : Pahl & Beitz [65] or Ulrich & Eppinger [85] |
| Eco-design principles come as a layer above standard design, and integrates tools such as LCA and EEA [1,10,48,49,79,80], actual user centered design principles are also presented as another layer [4,5,29,38,39,54] |
| Specific User-Centered Design methodologies include 4 basic phases: Analysis including field works, user definition and Kansei Engineering, Design Implementation and Deployment.<br>MEC theory [87,6,18] from the marketing research is a tool for translating the values to product attributes and comes across the Analysis and Design phase. |
| Eco-Kansei factors, user experience, usability, affordance and values perception come as an iterative group data that makes the link between the Standard Design method and UCD Methodologies. |

**Table 4. Theoretical assumptions of the new model.**

Following these assumptions, we can propose on Figure 9 below a theoretical framework model which integrates the various point of views presented in this article.

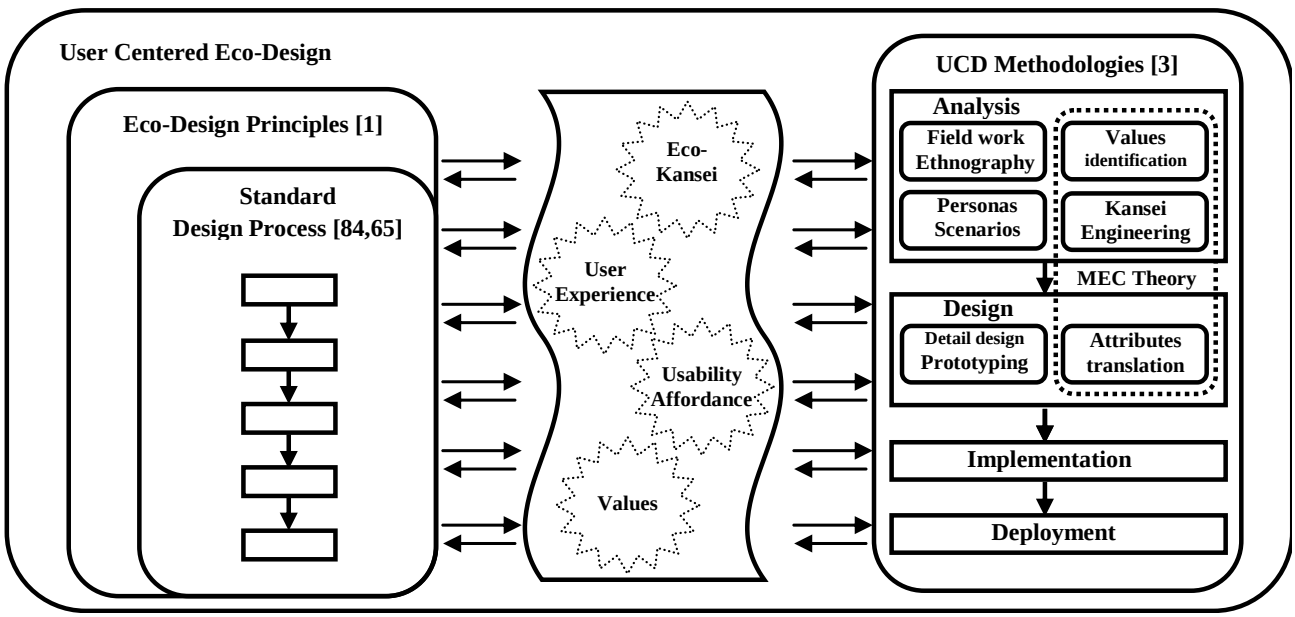


**Figure 9. Proposed basic framework for a User-Centered Eco-design methodology.**

## CONCLUSION

A major assumption in our research is that Kansei studies could expand our vision of user modeling for Eco-design by introducing advanced concepts in the subjective definition of users, and by building new user models encompassing complex dimensions such as eco-values and eco-moods. We focused here on studies that take into account the subjective perceptions of users of the products in design, with a particular interest in the notions of value and semantics towards the environment, as we believe Kansei studies are actually of a great interest for Eco-design. With regard to this, we introduced the notion of *Eco-Kansei* to define Kansei factors which are relevant for environmental awareness. *Eco-Kansei* may be associated with common User Centered Design techniques on its analysis phase, and clearly enriches the definition of end-user profiles or personas. Other Kansei factors are still implemented, then usability testing are conducted towards the development process to ensure that the solution fits with the user's usability profile.

Building a framework linking *Kansei Design*, *User Centered Design* and *Eco-design* is the main issue of this paper. According to a literature review, a new user model was proposed, which integrates the three key fields: *Eco-design*, *User Centred Design* and *Kansei*. This theoretical model is only set into a macro vision in order to let each area be further improved into more specific procedures, as protocols and task analysis will be applied in experimental context after selecting an industrial product to validate its effectiveness. To this end, the formalization of an applicable methodology of EcoUCD is the next step of this work. Besides, the long term objective of our work could be met by generating a concept of User Centered Design model with a particular attention to environmental interests, pushing obviously the research towards another level of consideration. That makes this window an interesting prospect for future applications of Kansei studies.

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